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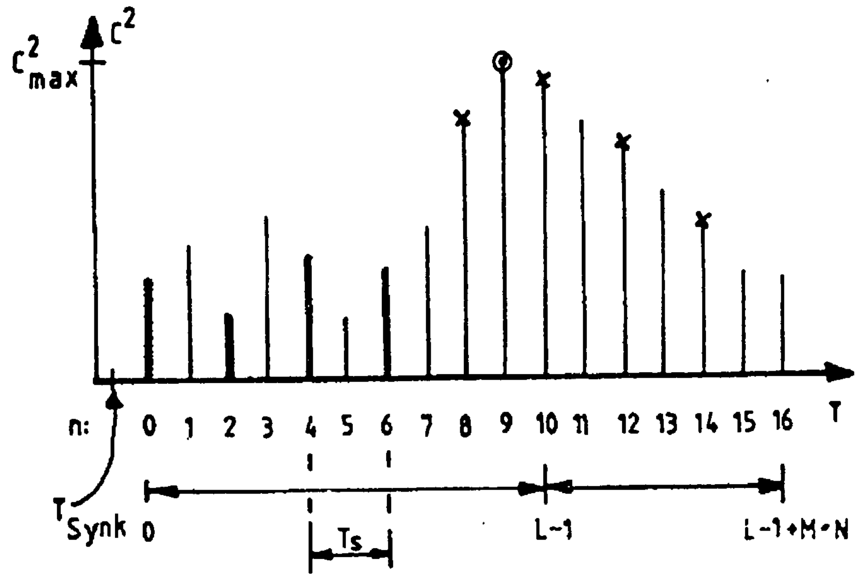
(54) **METHODE DE DETERMINATION DES TEMPS D'ECHANTILLONNAGE**

(54) **METHOD OF DETERMINING SAMPLING TIME POINTS**



(57) Des séquences de symboles présentant des séquences de synchronisation sont transmises sur un canal radio. Les signaux reçus sont échantillonés à intervalles aux points d'échantillonage de signaux dans le temps (n) et une réponse de canal (C^2) est obtenue par corrélation. La réponse des impulsions est échantillonée (Ts) pendant une période (M x N) qui correspond à la dispersion dans le temps du canal. Pour des échantillons séparés ayant des points de départ séparés (n), on obtient des estimations de canal (n = 0, 2, 4, 6, N = 1, 3, 5, 7...) dont on calcule les valeurs d'énergie, et on sélectionne l'estimation (n = 8, 10, 12, 14) ayant le plus d'énergie.

(57) Symbol sequences having synchronization sequences are transmitted over a radio channel. Received signals are sampled in signal sampling time points (n) and by correlation a channel response (C^2) is obtained. The impulse response is sampled (T) over a period (M x N) corresponding to time dispersion of the channel. For separate samples with separate start points (n), channel estimates are obtained (n - 0, 2, 4, 6, N = 1, 3, 5, 7,...) whose energy values are calculated, and the estimate (n = 8, 10, 12, 14) with the largest energy is selected. The first time point (n = 8) in this estimate is selected as sampling time point for the symbol sequence.

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On sélectionne le premier point dans le temps (n = 8) de cette estimation comme point d'échantillonage dans le temps pour la séquence des symboles. Dans une variante, on sélectionne le point d'échantillonage de signaux dans le temps (n = 9) ayant la valeur d'énergie maximale (C^2 max). En comparant ces valeurs d'énergie, on peut sélectionner l'un ou l'autre de ces points d'échantillonage de signaux dans le temps (n = 8, n = 9) comme point d'échantillonage dans le temps pour la séquence des symboles. Pour les séquences consécutives, on calcule une valeur moyenne relative aux points d'échantillonage dans le temps. Un maximum d'énergie pour les symboles reçus et une simplification du traitement des signaux sont ainsi obtenues.

Alternatively, the signal sampling time point (n = 9) with maximum energy value (C^2 max) is selected. By comparing the energy values either one of these signal sampling time points (n = 8, n = 9) can be selected as the sampling time point for the symbol sequence. For consecutive sequences, an average value for the sampling time points is calculated. Maximum energy of received symbols and simplified signal processing are obtained.

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A METHOD OF DETERMINING SAMPLING TIME POINTS

TECHNICAL FIELD

The present invention relates to a method of determining sampling time point when transmitting symbol sequences with recurrent synchronization sequences, wherein the symbol sequences are transmitted as analog signals over a channel and are liable to be subjected to disturbances during said transmission, said method comprising the steps of:

- sampling the received, analog signals at recurrent signal sampling time points which are selected in relation to a synchronization time point common to a transmitter and a receiver, wherein a time interval for transmission of a symbol, a symbol time, includes a whole number of signal sampling time points; and

- effecting channel correlation for calculating impulse response for the channel with the aid of the known synchronization sequences and the sampled, received signals.

PRIOR ART

In the radio transmission of digital information, a number of problems occur which must be solved in order to enable the receiver to discern the information originally transmitted. One example of these problems resides in transmitter and receiver synchronization. This problem has found many solutions for different applications and is well known to the skilled person. Another problem is that the transmitted signals are liable to be affected by various kinds of disturbances, for instance noise, fading and multi-path propagation. The difficulties associated herewith have been tackled in several ways. Thus, it is well known to transmit a known synchronizing word and to calculate an impulse response for the transmission channel between transmitter and receiver with the aid of the known synchronizing word. The transmitted, unknown information can be interpreted by the receiver

with the aid of the impulse response, and can be converted to an acoustic signal for instance, through a plurality of signal processing stages. A further example of the difficulties experienced with signal transition is one of controlling the receiver frequency in time with the transmitter frequency. This difficulty has been recognized and a number of well-known methods are found for controlling the frequency of the receiver. One problem, on the other hand, which would not appear to have awakened any particular interest is that of optimally utilizing the signal strength of the transmitted signal during the aforesaid transmission of digital information. It should be observed in this respect that in the case of multipath propagation a transmitted signal can be refound at several mutually different receiver time points. Despite research, both in the patent literature and in other sources, no publication has been found which deals with this problem.

DISCLOSURE OF THE INVENTION

The present invention is based on the concept of optimally utilizing the signal strength of a transmitted signal for the purpose of simplifying the signal processing necessary in a receiver. This optimization is achieved by selecting a time point for sampling the tranmitted symbols. This choice is based on a comparison of the energy content of different parts of the channel impulse response.

The invention has the characterizing features set forth in the accompanying Claims.

BRIEF DESCRIPTION OF THE DRAWINGS

An exemplifying embodiment of the invention will now be described with reference to the accompany drawings, in which

Figure 1 is a block schematic illustrating a part of a mobile telephony system;

Figure 2 illustrates time slots for time-shared transmission of information;

Figure 3 illustrates symbol sequences transmitted in a time-shared time slot;

Figure 4 illustrates a complex number plan with symbol values;

Figure 5 is a block schematic illustrating a channel estimation filter; and

Figure 6 is a diagram with an impulse response for the transmission channel.

BEST MODE OF CARRYING OUT THE INVENTION

Figure 1 schematically illustrates a radio transmission system. Signal processing, for instance channel coding, of the information to be transmitted is effected in a unit 1 and the information is sent to a digital/analog converter D/A in the form of digital signals. The converter sends analog signals to a transmitting radio unit RA1, which transmits the signals over a channel to a receiving radio unit RA2. This unit sends the received signals to an analog/digital converter A/D, in which sampling of the signal takes place at a relatively high rate. Sampling takes place at regular intervals at signal sampling time points, the number of which is generally referenced n, so as to obtain a sampled signal S(n). That part of the radio transmission system described hitherto is well known to the person skilled in this art. Synchronization, channel correlation and sampling of the signal S(n) takes place in a correlation-and-synchronization circuit KS, as described in more detail hereinafter. The actual method in which a sampling time point is selected during a sampling operation is the object of the present invention. The sampling signals are sent from the circuit KS for further signal processing, in the case of the illustrated embodiment to an equalizer V, which produces estimated symbols U. The inventive method of selecting sampling

time points provides improved signal processing in the equalizer V.

The aforedescribed radio transmission system may, for instance, form a part of a time-shared mobile telephony system. Subscribers in this system are regularly assigned recurring time slots 1,----, P as illustrated in Figure 2, in which T signifies time. One of the subscribers has been assigned the time slot numbered H and the symbol sequences designated SS1, SS2, SS3,---, are transmitted in this time slot. Each symbol sequence includes a synchronization sequence SY and a data sequence D and together take up the length of a time slot designated TO in Figure 3. The transmitted signals may be modulated in accordance with QPSK-modulation, as illusrated in Figure 4, for instance. In a complex number plan, with the axes designated I and Q, the four possible values of the symbols are marked one in each square with the binary digits 00, 01, 10 and 11. In the case of the aforesaid QPSK-modulation, the time taken to transmit a symbol, a symbol time Ts, is equal to the time for two binary digits.

Various kinds of disturbances are liable to occur during transmission of the symbols over the channel, for instance such disturbances as multipath propagation, as indicated with double signal paths in Figure 1. These disturbances change from one signal sequence to the immediately following sequence. In order to enable interpretation of the transmitted information contained in the data sequence D, the impulse response of the channel is determined in a known manner for each signal sequence. This is achieved by correlating the known synchronization sequence SY in the receiver with the received, sampled values S(n) in the synchronization sequence. Correlation is carried out in a filter, as illustrated in Figure 5. The filter has delay units 2, filter coefficients 3 and summators 4. The filter coefficients have the values SY_0---SY_{K-1} corresponding to the known synchronization word, the length of which is a K symbol sampling intervals. The received, sampled synchronization word S(n) is delayed in the delay unit 2, so as to subsequently obtain signals

S(n-N)---S(n-(K-1)N) which are stepwise delayed by one symbol sampling interval. The delayed signals are multiplied with their respective coefficients and summated in the summator 4. Subsequent to dividing with the value K in a circuit 5, the values C^2(n-(K-1)N) are obtained in the sampled impulse response for the channel between the radio units RA1 and RA2.

Figure 6 illustrates the sampled impulse response obtained in the aforedescribed manner for the synchronization sequence in the symbol sequence SS1. As in Figure 2, T designates the time and C^2 generally designates the energy for the discrete correlation values of the impulse response, these values being marked with columns at the signal sampling time point n. The impulse response has a length of L+M x N sample, which have been numbered from 0 to L-1+M x N in the Figure. In the illustrated case, N designates the number of signal sampling time points n for each symbol and according to the illustrative example N is equal to 2. The length of a channel estimate for the equilizer V in symbol times Ts is designated M, and in the case of the illustrative example, M is equal to 3. The length M x Ts of the channel estimate is determined by the magnitude of the time dispersion possessed by the channel, so that the equilizer V will be able to equalize dispersions which range up to M x Ts. The letter L designates the number of signal sampling time points over which the correlation must be carried out in order to ensure that the impulse response will cover a large and rapid change in the transmission properties of the channel. Normally, an interval which covers L example is called a correlation window. According to the sample illustrated in Figure 6, L=11 and the signal sampling time points n of the impulse response have been numberd from 0 to 16.

As mentioned in the introduction, sampling of the signal S(n) takes place in the correlation-and-synchronization circuit KS. This sampling takes place in step with the symbol timing at symbol sampling time points having an interval of one symbol time Ts between two mutually adjacent samples. The impulse response is also sampled in step with the symbol timing to a channel estimate, the length of which is selected to M symbol times Ts in

accordance with the aforegoing. It is possible, in accordance with the invention, to select a plurality of different channel estimates from the impulse response in Figure 6, this selection being effected in the following manner: A first sampling of the impulse response commences at the signal sampling time point n = 0. Sampling continues in the symbol sampling time points at each alternate sampling time point n = 2, n = 4 up to n = 6, where according to the illustrated embodiment N = 2 and M = 3. This channel estimate is marked in Figure 6 with heavily drawn columns. There is obtained in this way a channel estimate of length M x Ts, the total energy $E_{ke}(n)$ of which can be expressed generally by the relationship

$$E_{ke}(n) = \sum_{i=0}^{M} C^2(n+N \times i)$$

which constitutes a comparison value for the energy of the channel estimate. The next sampling of the impulse response commences at n = 1 and new values of the energy $E_{ke}(n)$ are subsequently calculated up to n = L-1, in the case of the illustrated embodiment n = 10. There is obtained in this way an L number of comparison values $E_{ke}(n)$ of which one has a largest magnitude and is designated $E'_{ke}(n)$. Those symbol sampling time points in the impulse response which give a channel estimate with this maximum energy has been marked with a cross in Figure 6. The channel estimate having the comparison value $E'_{ke}(n)$ is selected and the first sampling time point in the selected channel estimate is selected as the sampling time point. In the case of the illustrated embodiment of Figure 6, the sampling time point n = 8 is selected, which according to the aforegoing applies for the symbol sequence SS1.

According to the invention, the sampling time point can also be calculated in the following alternative manner. That signal sampling time point of the signal sampling time points <u>n</u> in which the impulse response has maximum amplitude $C^2_{max}(n)$ is sought and constitutes the selected sampling time point. The comparison value

in this sampling time point can be expressed with the simple relationship

$$E'_t(n) = \alpha \times C^2_{max}(n)$$

where α is a constant. $C^2_{max}(n)$ is marked with a ring in the Figure 6 example and the corresponding sampling time point is $n = 9$. This alternative method of selecting the sampling time point is beneficial when the impulse response has a single correlation value $C^2(n)$ which dominates over the remaining correlation values.

A combination of the two aforedescribed methods of selecting sampling time points also lies within the purview. The comparison value $E'_{ke}(n)$ and the comparison value $E'_t(n)$ are calculated in accordance with the aforegoing. The largest of these values E_{max} is selected and the corresponding signal sampling time point n_{max} constitutes the selected sampling time point.

The aforedescribed inventive method of selecting a sampling time point for one of the signal sequences according to the example SS1 has the advantage of simplifying the following signal processing step in, for instance, the equalizer V. It is possible, however, that the transmitted signal of the Figure 1 illustration has been subjected to fading, i.e. the signal strength has fallen radically over a short time interval due to signal interference. If the fading occurs during the synchronization sequence SY, the selected channel estimate and the selected sampling time point will not be representative of the remainder of the symbol sequence. This weakness is particularly noticeable in transmission systems which have long symbol sequences extending over several milliseconds. This weakness is counteracted in accordance with the present invention by calculating an estimated value $n_{est}(j)$ for the sampling time point iteratively. The maximum energy value, for instance E_{max}, and the corresponding sampling time point n_{max} is subsequently calculated for the sequences SS1, SS2, SS3---. The estimated sampling time point for the symbol sequence numbered j is calculated in accordance with the relationship

$$n_{est}(j) = n_{est}(j-1) + \beta\,(n_{max} - n_{est}(j-1))$$

In this case, $n_{est}(j-1)$ is the estimated sampling time point from the preceding symbol sequence; n_{max} belongs to the symbol sequence numbered $\underline{j}$ and β is a weighting function. This weighting function may, for instance, assume the value $\beta = \beta 0$ when E_{max} exceeds or is equal to a threshhold value E0, while in other cases β is equal to 0. Other average value formations can also be made. In general, the estimated sampling time point $n_{est}(j)$ will lie between two signal sampling time points $\underline{n}$ and the signal sampling time point which lies nearest $n_{est}(j)$ is selected as the sampling time point.

It should be noted that all time points of the receiver, for instance the signal sampling time points, are calculated in relation to a synchronization time point T_{sync} of a frame clock, which is controlled in a known manner.

The invention has been described in the aforegoing with reference to an exemplifying embodiment applied with time-shared mobile telephony. It will be understood, however, that the invention can also be applied with other signal transmission systems as soon as recurrent synchronization sequences are transmitted. The intervals between the synchronization sequences may have varying lengths.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A method of determining sampling time point when transmitting symbol sequences with recurrent synchronization sequences, wherein the symbol sequences are transmitted as analog signals over a channel and are liable to be subjected to disturbances during said transmission, said method comprising the steps of:

- sampling the received, analog signals at recurrent signal sampling time points which are selected in relation to a synchronization time point common to a transmitter and a receiver, wherein a time interval for transmission of a symbol, a symbol time, includes a whole number of signal sampling time points; and

- effecting channel correlation for calculating impulse response for the channel with the aid of the known synchronization sequences and the sampled, received signals c h a r a c t e r i z e d in that the method comprises the further steps of

- sampling the channel impulse response such as to obtain at least one channel estimate for one of the synchronization sequences (SY1), wherein the sampling for each channel estimate is carried out at a desired number of time points mutually spaced by the distance of one symbol time (Ts), a desired number of symbol sampling time points with a starting point in one of the signal sampling time points (n),

- calculating at least one comparison value ($E_{ke}(n)$, $E'_t(n)$ corresponding to the impulse response energy in at least one of the symbol sampling time points,

- selecting the largest ($E'_{ke}(n)$, $E'_t(n)$, E_{max}) of the comparison values, and

- selecting one of the signal sampling time points (n_{max}) which corresponds to the selected comparison value ($E'_{ke}(n)$, $E'_t(n)$, E_{max}) and constitutes the sampling time point for said synchronization sequence.

2. A method according to Claim 1, characterized in that the comparison value ($E'_{ke}(n)$) corresponds to the total energy of the impulse response in the desired symbol sampling time points for each of said channel estimates, wherein the signal sampling time point (n) corresponding to the comparison value ($E'_{ke}(n)$) coincides with the first symbol sampling time point of the channel estimate.

3. A method according to Claim 1, characterized in that one of the comparison values ($E'_t(n)$) corresponds to the impulse response energy in one of the signal amplitude time points in which the total impulse response has maximum amplitude, ($C^2_{max}(n)$), wherein said signal sampling time point is the signal sampling time point (n) that corresponds to the comparison value.

4. A method according to any one of Claims 1, 2 or 3, characterized in that the method further comprises the following steps of:

- selecting the sampling time points (n_{max}) for subsequent received synchronization sequences (SY1, SY2---), and

- forming an average value iteratively from the subsequently selected sampling time points (n_{max}) in order to obtain an estimated sampling time point ($n_{est}(j)$).

5. A method according to Claim 4, characterized by forming said average value with the aid of a weighting function (β) for the latest incoming synchronization sequence (j) with the latest selected sampling time point (n_{max}), wherein the weighting function assumes a zero value when the largest comparison value (E_{max}) is beneath a threshhold value (E0).

ABSTRACT OF THE DISCLOSURE

Symbol sequences having synchronization sequences are transmitted over a radio channel. Received signals are sampled in signal sampling time points (n) and by correlation a channel response (C^2) is obtained. The impulse response is sampled (T) over a period (M x N) corresponding to time dispersion of the channel. For separate samples with separate start points (n), channel estimates are obtained (n = 0, 2, 4, 6, N = 1, 3, 5, 7,...) whose energy values are calculated, and the estimate (n = 8, 10, 12, 14) with the largest energy is selected. The first time point (n = 8) in this estimate is selected as sampling time point for the symbol sequence. Alternatively, the signal sampling time point (n = 9) with maximum energy value (C^2 max) is selected. By comparing the energy values either one of these signal sampling time points (n = 8, n = 9) can be selected as the sampling time point for the symbol sequence. For consecutive sequences, an average value for the sampling time points is calculated. Maximum energy of received symbols and simplified signal processing are obtained.

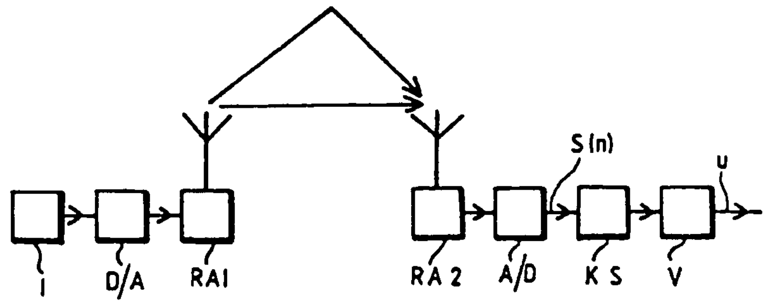

Fig.1

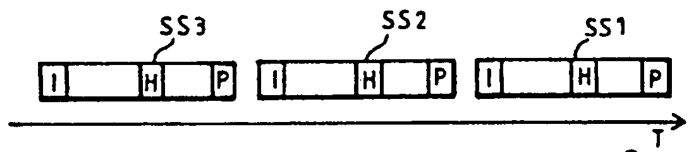

Fig.2

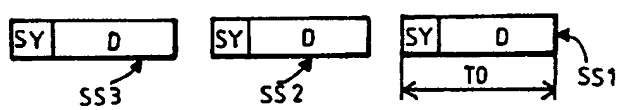

Fig.3

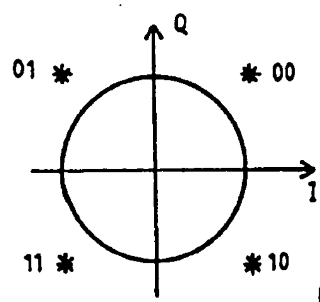

Fig.4

2/2

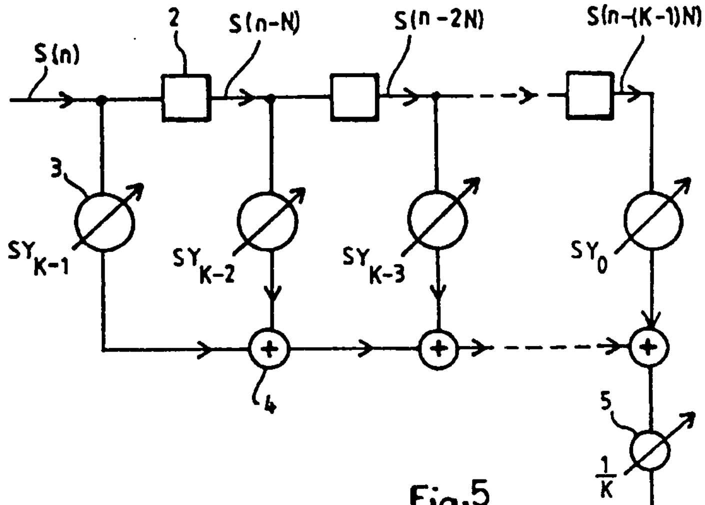
2
S(n-N)
S(n-2N)
S(n-(K-1)N)
S(n)
3
SY_{K-1}
SY_{K-2}
SY_{K-3}
SY_0
4
5
$\frac{1}{K}$

Fig.5

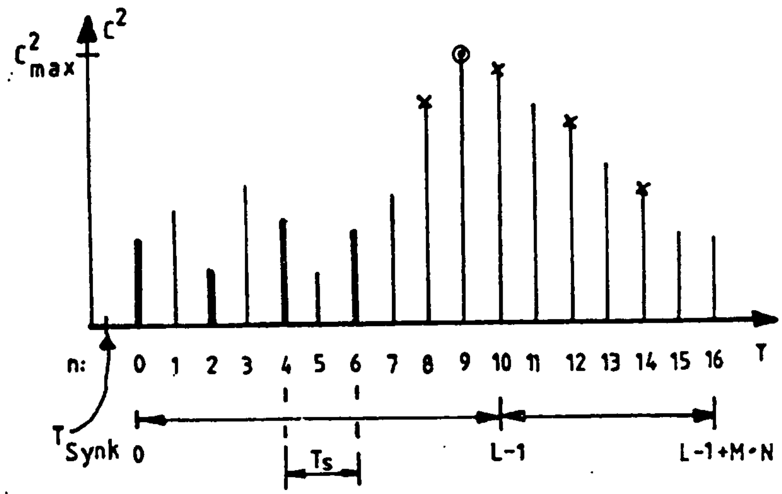
c^2_{max}
c^2
n: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
T
T_{Synk}
0
Ts
L-1
L-1+M·N

Fig.6